Dave Pushka's Block Raiser (Pivoter) Calculations for variable geometry

Detector Block Weights and Dimensions and Loads to Table:

Weight of a block	312,979	pounds	156.5	tons (short)	
Nominal Thickness of a block	2053.6	millimeters	80.85	inches	
Nominal Thickness of a block					
Nominal H or W of a Block	15.7	m	618.110236	in	51.5091863 ft
Volume of Block	17,876	ft3			
Apparent Density of Empty Block	17.5	#/ft3			
Block loading on table when horizontal	117.96	#/square foot			

Geometry of Table Pivot:

Goal Distance from table top to pivot (vertical direction when table horizontal)	4	inches	positive means that the pivot is below the top surface of the table when the table is horizontal
Vertical Distance from pivot to block c.g when table is horizontal	44.425	inches	equals half the thickness of a block plus the goal distance from the table top to the pivot shown right above
Horizontal Distance from Pivot to block c.g. when table is horizontal (positive number is toward the forks)	0.000	inches	zero undicates that the pivot is right under the block c.g., positive means that the pivot is towards the forks
L_block = Distance from block c.g. to pivot, inches	44.425	inches	calculated by the square of the sum of the squares.
L_table = Distance from table c.g. to pivot, inches	32.25	inches	calculated by the square of the sum of the squares.

Moments Generated by the Block Weight on the Table When Vertical:

Moment from block weight about pivot when table is vertical	13,904,173	inch-pounds	1,159	kip-ft	
Theta0_Block is the initial angle above horizontal from the pivot to the block c.g.	1.571	radians	90.0	degrees	
Theta0_Table is the initial angle above horizontal from the pivot to the table c.g.	-1.571	radians	-90.0	degrees	
Moment from block weight on the table 'forks' when the block is vertical	12,652,255	inch-pounds	1,054	kip-ft	this is the maximum bending moment at the base of the 'forks' supporting the cantilevered block.

Moments as a Function of the table rotation (0=table horizontal):

Table Angle above horizontal (degrees and radians):	Table Angle (top surface above horizontal) degrees	radians	Angle from table pivot to block c.g. (from horizontal) degrees	radians	Angle from table pivot to table c.g. (from horizontal) degrees	radians	Cosine of Angle to block c.g.	Cosine Angle to table c.g.	Block Weight pounds	Table Weight pounds	Block Distance to Pivot	Table Distance to Pivot	Moment Due to Block (cw = +) in-lbs	Moment Due to Table (cw = +) in-lbs	Sum of Moments from Block and Table (cw = +) in-lbs
	0	0	90	1.57	-90	-1.571	0.0000	0.0000	312,979	218,226	44.425	32.25	31	22	53
	15	0.2618	105	1.83	-75	-1.309	-0.2588	0.2588	312,979	218,226	44.425	32.25	-3,598,634	1,821,536	-1,777,098
	30	0.5236	120	2.09	-60	-1.047	-0.5000	0.5000	312,979	218,226	44.425	32.25	-6,952,059	3,518,916	-3,433,143
	45	0.7854	135	2.36	-45	-0.785	-0.7071	0.7071	312,979	218,226	44.425	32.25	-9,831,713	4,976,488	-4,855,225
	60	1.0472	150	2.62	-30	-0.524	-0.8660	0.8660	312,979	218,226	44.425	32.25	-12,041,351	6,094,920	-5,946,432
	75	1.3090	165	2.88	-15	-0.262	-0.9659	0.9659	312,979	218,226	44.425	32.25	-13,430,392	6,797,993	-6,632,399
	90	1.5708	180	3.14	0	0.000	-1.0000	1.0000	312,979	218,226	44.425	32.25	-13,904,173	7,037,794	-6,866,378
	90	1.5708	180	3.14	0	0.000	-1.0000	1.0000	0	218,226	0	32.25	0	7,037,794	7,037,794
	75	1.3090	165	2.88	-15	-0.262	-0.9659	0.9659	0	218,226	0	32.25	0	6,797,993	6,797,993
	60	1.0472	150	2.62	-30	-0.524	-0.8660	0.8660	0	218,226	0	32.25	0	6,094,920	6,094,920
	45	0.7854	135	2.36	-45	-0.785	-0.7071	0.7071	0	218,226	0	32.25	0	4,976,488	4,976,488

30	0.5236	120	2.09	-60	-1.047	-0.5000	0.5000	0	218,226	0	32.25	0	3,518,916	3,518,916
15	0.2618	105	1.83	-75	-1.309	-0.2588	0.2588	0	218,226	0	32.25	0	1,821,536	1,821,536
0	0	90	1.57	-90	-1.571	0.0000	0.0000	0	218,226	0	32.25	0	22	22

Forces on a Cylinder Resulting from the above Moments:

Horizontal Location of Cylinder Top w.r.t Table Pivot	-72.0001	inches	positive is towards the forks
Vertical Location of Cylinder Top w.r.t. Table Pivot	-72	inches	positive is up
Horizontal Location of Cylinder Bottom w.r.t Table Pivot	-72	inches	positive is towards the forks
Vertical Location of Cylinder Bottom w.r.t. Table Pivot	-167.0001	inches	positive is up
Closed Length of the cylinder	95	inches	
Radius from Table Pivot to top of cylinder point	101.82	inches	
Initial Angle above horizontal from Table Pivot to top of cylinder point	-0.785	radians	
Initial Angle above horizontal from Table Pivot to top of cylinder point	-45.00003979	degrees	
Length of the 'ground' link from table pivot to stationary cylinder end pivot at the bottom of the cylinder	181.9	inches	
Fixed Angle above horizontal from Table Pivot to bottom of cylinder end pivot, Theta	-66.67731577	degrees	
Initial Angle between the 'ground' link and the line (r) from the table pivot to the top of the cylinder, Lambda	21.67727598	degrees	

Table Angle above horizontal (degrees and radians):	Table Angle (top surface above horizontal) degrees	Sum of Moments from Block and Table (cw = +) in-lbs	Vertical Component of Cylinder Extension inches	Horizontal Component of Cylinder Extension inches	Cylinder Extension	Cylinder Angle c.w. from vertical degrees	Vertical Lever Arm to Cylinder Top inches	Horizontal Lever Arm to Cylinder Top inches	Hydraulic Cylinder Force (- = tension, + = Compression) pounds	Hydraulic Cylinder Force (- = tension, + = Compression) tons
On the way Up:	0	53	0.00	0.00	0	0.000	72.00	72.00	1	0.0
(with block Load)	15	-1,777,098	21.09	16.18	27	7.648	50.91	88.18	-18,871	-9.4
	30	-3,433,143	45.65	26.35	53	10.278	26.35	98.35	-33,831	-16.9
	45	-4,855,225	72.00	29.82	78	9.931	0.00	101.82	-48,408	-24.2
	60	-5,946,432	98.35	26.35	102	7.695	-26.35	98.35	-63,301	-31.7
	75	-6,632,399	122.91	16.18	124	4.238	-50.91	88.18	-78,790	-39.4
	90	-6,866,378	144.00	0.00	144	0.000	-72.00	72.00	-95,366	-47.7
On the way down:	90	7,037,794	144.00	0.00	144	0.000	-72.00	72.00	97,747	48.9
(without block load)	75	6,797,993	122.91	16.18	124	4.238	-50.91	88.18	80,757	40.4
	60	6,094,920	98.35	26.35	102	7.695	-26.35	98.35	64,881	32.4
	45	4,976,488	72.00	29.82	78	9.931	0.00	101.82	49,617	24.8
	30	3,518,916	45.65	26.35	53	10.278	26.35	98.35	34,677	17.3
	15	1,821,536	21.09	16.18	27	7.648	50.91	88.18	19,342	9.7
	0	22	0.00	0.00	0	0.000	72.00	72.00	0	0.0

Dave Pushka's Block Raiser (Pivoter) calculations for the top table made from plate steel:

Initial Guesses:		
Assumed weight of table	300,000	pounds
Required Distance from pivot to table c.g. if the table is to balance the block when the block is vertical	46.3	inches
Required thickness of table assuming homgenous	100.7	inches
Table Dimensions and Thicknesses:		
Thickness of Table Top Plates	0.25	inches
Thickness of table bottom plates	0.25	inches
Thickness of table vertical shear webs	0.25	inches
No. of shear webs in the beam direction	26	
No. of shear webs perpendicular to the beam direction	26	
Distance between shear webs in beam direction	1.981	feet
Distance between shear webs perpendicular to the beam direction	1.981	feet
Thickness of table shear plates in the vertical direction when horizontal	6	feet
Weight of Table Top in pounds per square foot	10.208	pounds per square foot
Weight of Table Bottom in pounds per square foot	10.208	pounds per square foot
Weight of shear webs in pounds per square foot	10.208	pounds per square foot
Table Weight:		
Weight of Table Top in pounds	27,085	pounds
Weight of Table Bottom in pounds	27,085	pounds
Weight of Table shear webs in pounds	164,057	pounds
Weight Sub Total	218,226	pounds
Assumed Number of Table Pieces for Shipping	6	
Table Piece Width, feet	8.585	feet
Table Piece Weight, pounds	36,371	pounds
Table C.G.		
Distance from Table Top Surface to Top Plate c.g.	0.125	inches
Distance from Table Top Surface to Bottom Plate c.g.	72.375	inches
Distance from Table Top Surface to Shear Plate c.g.	36.25	inches
Table Top Contribution to c.g.	3,386	inch pounds
Table Bottom Contribution to c.g	1,960,256	inch pounds
Table Shear Contributions to c.g.	5,947,057	inch pounds
Sub Total of Contributions to c.g	7,910,699	inch pounds
Sum of Contributions divided by weight	36.250	inches

Moments Generated by Table Weight about Pivot When Vertical:

Goal Distance from table top to pivot (vertical direction when table horizontal)	4	inches
Distance from Table Pivot to c.g.	32.250	inches
Moment Generated by Table Weight about Pivot when table is vertical:	7,037,794	inch-pounds
Moment Generated by Table Weight about Pivot when table is vertical:	586	kip-ft

Sum of Moments about Table Pivot When Vertical:

Moment Generated by Table Weight about Pivot when table is vertical:	7,037,794	inch-pounds
Moment from block weight about pivot when table is vertical	(13,904,173)	inch-pounds
Moment Sum when table is vertical:	(6,866,378)	inch-pounds
Moment Sum when table is vertical:	(572,198)	foot-pounds

This means that the table provides more of a moment about the pivot than the complete block does. This moment tends to make the loaded table move to the horizontal position.

Assumed Distance from Pivot to Cylinder Connection in the horizontal Direction, feet	6	feet
Number of Cylinders acting together	2	
Initial Cylinder Load when loaded table is horizontal		pounds

Moment of Inertia for the Table:
Top and Bottom Plates:

Follow sketch of un-equal rectangles on AISC 9th Ed. ASD Pg. 6-19		
b = b1 = table width in inches = b9*12	618.1	inches
t = top plate thickness = b26	0.25	inches
t1 = bottom plate thickness = b27	0.25	inches
d1 = shear plate depth = b33	72.0	inches
A = b*t + b1 * t1	309.1	in^2
c = ((0.5*b*t^3) + (b1*t1*(d-0.5*t1))/A	36.25	inches
y = c - t/2	36.13	inches
d =	72.50	inches
c1 = d - c	36.38	inches
y1 = c1 -(t1/2)	36.25	inches
I =((b*t^3)/12) + b*t*(y^2) + ((b1*t1^3)/12) + b1*t1*(y1^2)	404,721	inches^4

Web Plates:

bw = Web thickness, inches	0.25	inches
dw = Web depth, inches	72	inches
Iw - moment of inertia for one web	7776	inches^4
Number of webs:	26	
Iw total, I for all the webs combined	202,176	inches^4
Aweb = the area of one web, inches^2	18	inches^2
Aweb total = the area of all webs combined, inches^2	468	inches^2

Combining the Top and Bottom Plates and the Webs:

dna = distance from the n.a of the top & bttm to the n.a of the web	0	inches
Moment of inertia of the web about the n.a. of the top and bottom plates = Iw total +dna^2*Aweb total	202,176	inches^4
Icomb = I (top&bttm) + I web (w.r.t. top & bttm n.a)	606,897	inches^4
y = dimension from n.a to extream fiber = c, inches	36.25	inches

Bending Stresses on the Table when horizontal:

Let the beam direction be called 'x'
Let the direction perpendicular to the beam be called 'y'

In the x direction, the uniform load is from both the block and the table weight.

Block weight	312,979	pounds	
Table Weight	218,226	pounds	
Sum of Block and Table weights:	531,206	pounds	
Area of Table (based on L x W from above)	2653.2	ft2	
Uniform Load on Table	200.21	pounds per square foot	
Uniform Load on Table per unit Length	10,313	pounds per foot	
Bending Moment on Table	3,420,246	foot-pounds	Moment, M = uniform load, w, * ((the table length/2)^2)/2
Bending Moment on Table	41,042,953	inch-pounds	
Bending Moment on Table	41,043	kip-in	

Bending Moments about 'y':
One simple support at the center of the table, cantilevered up stream and downstream directions.
M=(w*L^2) / 8 where
Bending stress, Sigma = My/I

Bending Moment on Table	41,042,953	inch-pounds
Distance to extream fiber, y (inches)	36.25	inches
Moment of Inertia, combined table section, Icomb	606,897	inches^4
Bending Stress, sigma, (psi)	2,451	psi

Deflection of Tablewhen Horizontal:

In the beam direction, x where the table is cantilevered, the deflection of the far end is: delta1 = w*l^4/(8EI)

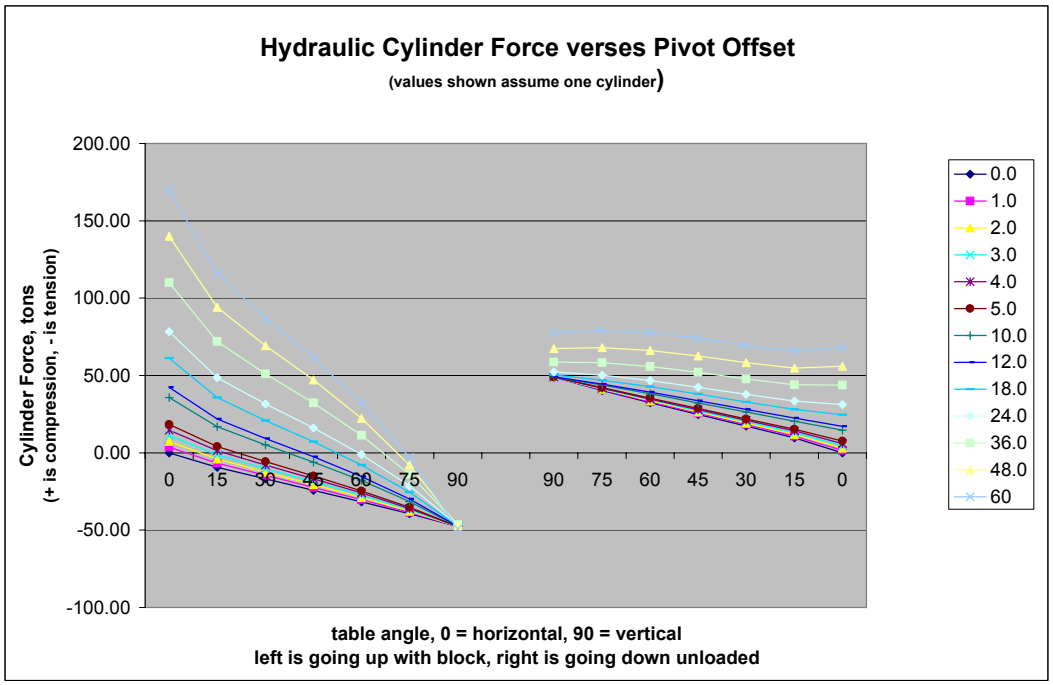
w = uniform distributed load	10,313	pounds per foot
l = length = the length of the cantilever = half the table length	309.1	inches
Young's Modulus, E (psi)	29,000,000	psi
Moment of Inertia, combined table section, Icomb	531,206	inches^4
delta1 =	0.76	inches
Fraction of the deflection due to the block loads	0.59	
Magnitude of the deflection due to the block loads	0.45	inches

If a support were added to the ends of the table to change the beam from cantilevered to the loading shown on AISC 9th Edition Page 2-299, Case 12, In the beam direction, the deflection of the far end is: delta1 = w*l^4/(185EI)

w = uniform distributed load	10,313	pounds per foot
l = length = the length of the cantilever = half the table length	309.1	inches^4
Young's Modulus, E (psi)	29,000,000	psi
Moment of Inertia, combined table section, Icomb	531,206	inches^4
delta1 =	0.03	inches
Fraction of the deflection due to the block loads	0.59	
Magnitude of the deflection due to the block loads	0.02	inches

Analysis of the Pivot Position and the resulting Hydraulic Cylinder Loads:

Horizontal Distance from Pivot to block c.g. when table is horizontal (positive number is toward the forks)		0.000 inches	0.0 inches	1.0 inches	2.0 inches	3.0 inches	4.0 inches	5.0 inches	10.0 inches	12.0 inches	18.0 inches	24.0 inches	36.0 inches	48.0 inches	60 inches
Table Angle above horizontal (degrees and radians):	Table Angle (top surface above horizontal) degrees	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons	Hydraulic Cylinder Force (- = tension, + = Compression) tons
On the way Up:	0	0.0	0.00	3.69	7.37	11.03	14.68	18.29	35.76	42.41	61.15	78.34	109.97	140.08	169.88
(with block Load)	15	-9.4	-9.44	-6.71	-3.99	-1.29	1.40	4.07	16.99	21.91	35.81	48.59	72.02	94.11	115.76
	30	-16.9	-16.92	-14.65	-12.39	-10.14	-7.90	-5.68	5.08	9.19	20.82	31.53	51.10	69.34	87.00
	45	-24.2	-24.20	-22.33	-20.46	-18.60	-16.75	-14.92	-6.01	-2.61	7.07	16.01	32.25	47.16	61.35
	60	-31.7	-31.65	-30.24	-28.83	-27.42	-26.02	-24.64	-17.90	-15.30	-7.91	-1.05	11.32	22.37	32.57
	75	-39.4	-39.39	-38.58	-37.76	-36.95	-36.14	-35.34	-31.42	-29.89	-25.47	-21.33	-14.01	-7.96	-2.89
	90	-47.7	-47.68	-47.68	-47.68	-47.68	-47.68	-47.68	-47.61	-47.54	-47.22	-46.81	-46.43	-47.17	-49.01
On the way down:	90	48.9	48.87	48.87	48.87	48.88	48.88	48.89	49.06	49.24	50.31	52.31	58.74	67.43	77.46
(without block load)	75	40.4	40.38	40.71	41.05	41.38	41.72	42.05	43.75	44.48	47.00	50.13	58.22	68.10	79.10
	60	32.4	32.44	33.02	33.60	34.18	34.75	35.32	38.13	39.26	42.79	46.69	55.76	66.21	77.57
	45	24.8	24.81	25.58	26.34	27.11	27.87	28.62	32.28	33.71	37.99	42.40	52.03	62.64	73.96
	30	17.3	17.34	18.27	19.20	20.12	21.04	21.95	26.33	28.02	32.92	37.75	47.72	58.31	69.41
	15	9.7	9.67	10.79	11.91	13.01	14.12	15.21	20.44	22.42	28.06	33.41	43.94	54.68	65.72
	0	0.0	0.00	1.51	3.03	4.53	6.02	7.49	14.53	17.17	24.52	31.23	43.75	55.97	68.23


Hydraulic Cylinder Force verses Pivot Offset
(values shown assume one cylinder)
Cylinder Force, tons
(+ is compression, - is tension)
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
0
15
30
45
60
75
90
90
75
60
45
30
15
0
0.0
1.0
2.0
3.0
4.0
5.0
10.0
12.0
18.0
24.0
36.0
48.0
60
table angle, 0 = horizontal, 90 = vertical
left is going up with block, right is going down unloaded